ISSN 0704-3716

Canadian Translation of Fisheries and Aquatic Sciences

No. 5417

The harvesting and cultivation of mollusks of the family Pectinidae (scallops) in various parts of the world: current situation and future prospects

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Original title: Bilan et perspectives de la pêche et de la culture des Pectinidés (coquilles Saint-Jacques et pétoncles) dans le monde

In: La pêche maritime, 1983, p.704-712

Original language: French

Available from:
Canada Institute for Scientific and Technical Information
National Research Council
Ottawa, Ontario, Canada K1A 0S2

1988

29 typescript pages

The harvesting and cultivation of molluscs of the family Pectinidae (scallops) in various parts of the world: current situation and future prospects

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In the course of the past decade, world scallop production has risen steadily from 135 000 tonnes in 1970 to 430 000 tonnes in 1978. This study analyses currently available information on the distribution and biology of scallops, production techniques (fishery and aquaculture) and market needs, and attempts, in the light of this information, to assess the outlook for expansion in world production.

Description and distribution of the leading commercial species

The family Pectinidae is a widespread one, comprising more than 350 species. All of these are exclusively sea-dwelling, but different species occur in many different habitats, from the lower tidal range limit to depths of between 1000 and 2000 metres. Most of them do not exceed 1 to 5 cm in size; of the larger species, only a few are sufficiently abundant to be harvested commercially.

In fact, commercially exploitable species of scallop number no more than fifteen or so. The maximum size of individual members of these species ranges from 5 cm to 20 cm. There are two major groups of commercial species, the Pecten group and the Chlamys group[2]. In Europe, of course, it is readily

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[1]Institut scientifique et technique des pêches maritimes = institute of marine fisheries science and technology

[2]In English-speaking countries the term "scallop" denotes a member of either group, but in most French-speaking countries members of the Pecten group are termed "coquilles saint-Jacques", while members of the Chlamys group are designated "pétoncles". In French-speaking regions of Canada the Placopecten magellanicus is known as the "pétoncle géant" (giant scallop).

apparent to which group a particular specimen belongs, but a universally applicable criterion is difficult to define none the less, as even within the Pecten group there are species in which both valves are convex and virtually devoid of crenations. Biologists have developed a complex set of distinguishing characteristics, but for the purposes of this study we shall rely, for the sake of simplicity, on the two auricles, which are virtually symmetrical in members of the Pecten group but asymmetrical in members of the Chlamys group (see Fig. 1).

The bulk of world production consists of members of the Pecten group, the generally larger size of which is a major advantage in commercial terms. Three Pecten species account for 75% of the total:

- Placopecten magellanicus, which is harvested in the northwestern Atlantic (nearly 200 000 tonnes);
- Patinopecten yessoensis, which is harvested in the northwestern Pacific (over 120 000 tonnes);
- Pecten maximus, which is harvested in the northeastern Atlantic (30 000 tonnes).

Other species of lesser importance are harvested:

- in the Atlantic, along the coast of North America (Argopecten irradians, A. gibbus, Chlamys islandica and C. tehuelca) and the coast of Europe (Chlamys opercularis, C. varia and C. islandica);
- in the Pacific, along the coast of North America (Patinopecten caurinus, Argopecten purpuratus) and in the waters off New Zealand (Pecten novaezaelandiae);
- in the Indian Ocean, in the waters off Australia (Pecten meridionalis and P. alba).

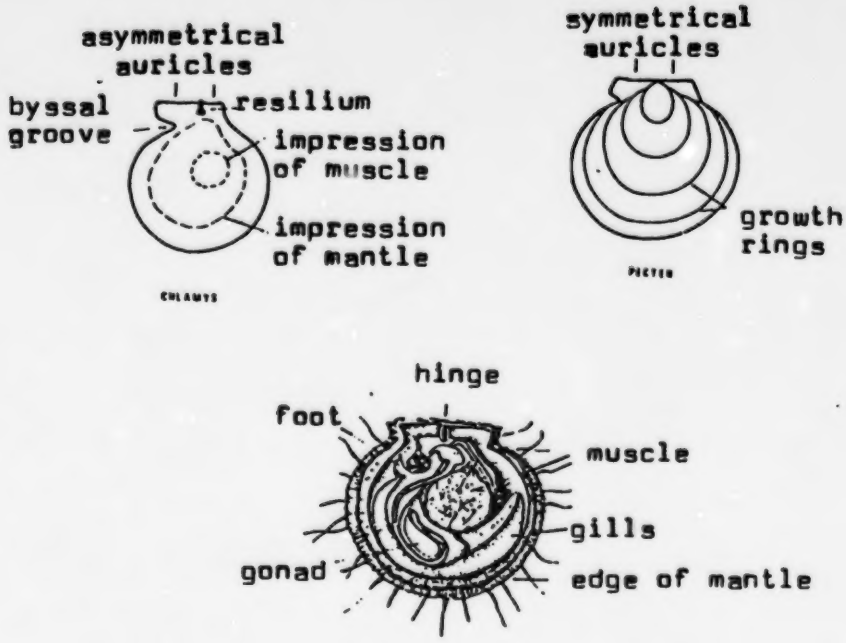

Fig. 1. Top: A Chlamys valve and a Pecten valve compared.
Bottom: Anatomy of a Pectinid (after Haynes, 1966).

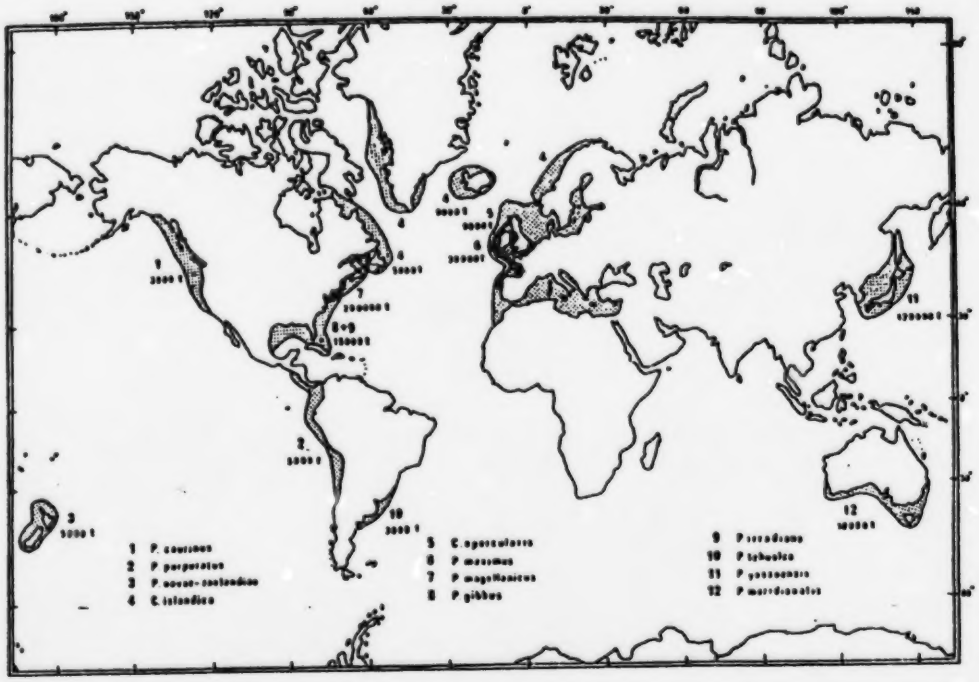

Fig. 2. Ranges of twelve species of scallops that are harvested in various regions of the world.

The ranges of the leading commercial species and current production levels in the various fisheries are shown in Fig. 2. As will be seen, these commercial species occur in abundance mainly in temperate waters (characterized by temperatures of between 5° and 25°C), especially those of the northern hemisphere. Table 1 shows the main distribution characteristics of the most important species.

The environmental requirements of any given species, i.e. those relating to the temperature and salinity of the water in which it can live, define the boundaries of the range of that species. The species we have been discussing, which are confined essentially to the continental shelves, in water that is between 5 m and 60 m deep for the most part, are in general able to tolerate annual variations in temperature of between 10° and 20°C and variations in salinity of the order of 5% to 10%. Scallops, however, differ from mussels and oysters in that they are unable to isolate themselves entirely from their environment, as the valves of their shells do not close tightly enough to make a watertight seal, and consequently they are sensitive to abrupt changes in environmental conditions (such as a reduction in oxygen content or salinity). Accordingly, they live primarily in coastal regions that are subject to the influence of offshore waters. Generally speaking, the type of bottom is not of great importance, although it is true that scallops tend to avoid areas where the bottom consists of nothing but mud or is excessively rocky, preferring areas of mixed bottom conditions including a substantial fraction of coarse sand and gravel.

Main biological characteristics

The Pectinidae are bivalve mollusks. They are filter feeders, obtaining their nourishment from microscopic algae, spores, bacteria, the eggs and larvae

of invertebrates, and sometimes even small planktonic crustaceans. Biologists distinguish three basic stages in their life cycle.

The first of these is the larval stage. Scallop larvae are free-swimming creatures that lead planktonic lives, using their broad cilia for locomotion within the water of their habitat. In search of their food, they rise to near the surface during the night and descend close to the bottom during the day. This development period, which is of short duration (from 15 days to two months) is of critical importance, for the larvae are so small (0.1 to 0.5 mm) that they are extremely vulnerable to fluctuations in temperature and salinity. Under unfavourable conditions, indeed, an entire year's production of larvae may die off during this time. Furthermore, currents may carry larvae away from areas that are conducive to their further development. When the larvae have grown to between 0.3 and 0.5 mm in size, they undergo a major transformation into what resemble miniature adults. This metamorphosis also marks the beginning of sedentary life.

As a rule, a scallop attaches itself to a substrate close to the bottom by secreting a tuft of filaments known as the byssus, which intervenes between the base of the creature's foot and the substrate; the substrate may be an empty shell, a frond of algae, a bryozoan or a fragment of gravel. The sedentary phase may continue for the rest of the individual's life in the case of some species, but in the case of most of the commercially exploited species it lasts only a few months, until the spat have grown to a size of between 0.5 cm and 2 cm. It is important to note that generally speaking, places conducive to the adherence of spat are found in the same areas year after year. Eddies, for example, constitute natural "larva traps" that foster adherence; they also act as food concentrators, thereby fostering growth as well. During the sedentary period of their lives scallops have extremely fragile shells, and mortality

remains high, partly because of natural phenomena such as abrupt changes in temperature as a result of unstable thermoclines and predation by starfish, crustaceans, gastropods, nudibranchs, and benthic and demersal fish, and partly because of injuries inflicted by fishing gear such as dragnets and trawls. As the sedentary phase draws to a close, the scallop's foot atrophies and the byssus disappears. The final phase, marked by free movement, now begins.

Like most Pectinidae, scallops move by means of a unique locomotive technique that amounts to a form of jet propulsion: the creature draws water into its body cavity, closes its mantle, and then vigorously expels the water through the slits located at the base of the auricles. This form of locomotion has its limitations, however, for in only a few seconds the scallop falls back on to the bottom after travelling a distance of not more than several metres at most. As a rule, the technique is used only for escape in an emergency, the directional factor being of little importance. As a result, scallop beds tend to develop in, or a very short distance away from, areas that are suitable for adherence during the second phase of their life cycle. Specimens are very unevenly distributed on the bottom; the occurrence of high-density patches is governed by features of the bottom topography (such as rippled ground, the periphery of a rocky plateau, or an undersea valley) or by breaks in the coastline (bays, fjords, lochs, rias and the like).

Growth in scallops follows a seasonal pattern that is affected by the factors of temperature and food supply. From spring to autumn, growth is rapid: juveniles of the largest species (Pecten maximus, Patinopecten yessoensis, Placopecten magellanicus) may grow at a rate of between 5 mm and 10 mm per month during this part of the year. In winter, on the other hand, growth proceeds more slowly or ceases altogether. When it resumes the following spring, a ring is observable on the shell. These growth rings that appear in successive years afford a convenient means of determining an individual's exact age.

The onset of sexual maturity is usually associated with a slower rate of growth, and this phenomenon recurs in progressively more pronounced form as ageing proceeds. The first sexual maturity occurs early in life, between the ages of one and three years in most species. Pectinidae are hermaphroditic as a rule, but some species are characterized by individuals of separate sex. Where this is the case, differential growth rates in males and females have not been reported.

During maturation, the gonad swells, and the male part of it becomes cream-coloured while the female part turns orange, reddish-orange or red. The emission of gametes and fertilization occur directly in the environment. One female may emit between 5 million and 200 million eggs per year, depending on the size of the individual concerned, but the numbers of adult scallops ultimately resulting from this profusion are very much smaller. As a rule, the male gametes are emitted a short time earlier than their female counterparts, and it seems unlikely that self-fertilization occurs. The point is an important one, for as the gametes can survive for only a short time, fertilization will tend to occur more frequently in high-density scallop beds, and will be unlikely to occur at all where individuals are too widely dispersed. Reproduction in scallops may be a concentrated phenomenon that occurs only once a year, or it may be spread over a longer period, depending to some extent on the species, but depending to a much greater extent on the particular population within a species. A population with an extended reproduction period will tend to be characterized by greater recruitment stability than one that reproduces over a shorter time span, since the latter may fail to reproduce altogether where conditions are unfavourable to the survival of larvae or spat. Different populations also display marked differences in heat tolerance, and the higher the temperature to which a population is acclimatized, the higher the lethal temperature for that population (Dickie and Medcof, 1963).

Once the final stage of the life cycle, the free-movement stage, has been attained, most Pectinidae become less sensitive to changes in environmental conditions. To be sure, sudden mass-mortality events associated with abrupt changes in water temperature or salinity do occur on rare occasions, but by and large it is true to say that most natural mortality among juveniles and adults is the result of predation. Scallops less than 5 cm in size are devoured in large numbers by large crustaceans, fish (including rays, gurnards and gadids), starfish, boring gastropods, and some sea birds and marine mammals. Larger scallops possess shells that are thick enough to protect them from most of these predators, and natural mortality is lowest among specimens in this category (natural mortality rates of between 10% and 20% are commonly estimated for the commercially harvested species such as Pecten maximus, Placopecten magellanicus and Patinopecten yessoensis). These large adult scallops have only a few serious predators, notably starfish and dog whelks; to these we may add some sponges of the genus Cliona and boring worms of the genus Polydora, which invade the valves and may cause death. Finally, as the individual approaches the end of its life-span, mortality again increases; the muscle begins to degenerate, so that the scallop finds it increasingly difficult to close its shell and hence becomes progressively more vulnerable to predators.

Fishing as the mainstay of commercial scallop production

The harvesting of natural beds of Pectinidae is an activity that has been practised since remote antiquity. Prehistoric hunter-gatherers picked up scallops by hand along beaches or after storms. As time went on, they must have learned how to use small boats to explore inshore waters and taken to collecting scallops in a more systematic fashion with rakes. At this period mollusks were

already coming to be in demand, not only as food but also as a source of raw material for the making of utensils and decorative objects of various kinds. This primitive and inefficient type of harvesting continued until the invention of the dragnet and the pole trawl made it feasible to harvest scallops in sufficiently large quantities for them to become items of trade. It is clear that scallop shells were well known in Europe as long ago as the Middle Ages, when they were symbolically displayed by persons who had made the pilgrimage to the shrine of Saint James of Compostella. In China, the dried meat of Japanese scallops was highly prized.

By the early twentieth century, world production had reached a level which we may estimate at somewhere between 20 000 and 30 000 tonnes annually. Japan accounted for half of this total, Europe and North America for the remainder. Subsequently, the use of motorized fishing boats and the adoption of on-board winches, the development of new preservation techniques, and the advent of more effective means of distribution brought about a great expansion in scallop harvesting.

This expansion took place only slowly in North America, however, and more slowly still in Europe, as the abundance of agricultural products in those parts of the world held down demand for scallops as food. In Japan, on the other hand, where much of the population lived mainly on the products of the sea, most of the country's resources of Pectinidae were already being exploited by 1915 (landings in that year amounted to 50 000 tonnes). After the first World War production increased very rapidly, rising to 80 000 tonnes by 1934 (see Fig. 3). However, catches declined steadily thereafter, as overharvesting made it impossible for the scallop populations in the Sea of Japan to maintain their numbers. By the 1960s landings had fallen off to between 5000 and 10 000 tonnes yearly, and the scallop fishery was extinct everywhere but on the island of

Hokkaido (Lake Samora and the Bay of Funka) and the northern part of Honshu (Mutsu Bay). Yet this collapse of the industry had its beneficial aspect, in that it impelled the Japanese to turn their attention to the development of scallop-cultivation techniques. The results have been impressive: Japan's production of scallops increased twentyfold between 1968 and 1979, and the country has now recovered its old position as a leading producer, with a total of 120 000 tonnes a year.

In North America, a scallop fishery grew up at the end of the nineteenth century in areas near the great east coast cities of New York, Boston, Portland and Halifax. Two species occur in those waters, the bay scallop (Argopecten irradians) and the giant scallop (Placopecten magellanicus). The former is a small species that seldom grows to a size of more than 8 or 9 cm; its habitat consists exclusively of shallow water, in estuaries for the most part, south of Cape Cod. The latter species is much larger (individuals measuring as much as 18 to 20 cm have been reported), its range extends further north, from Cape Hatteras to Newfoundland, and it is found from low-tide mark out to a water depth of 150 metres. By the early 1930s United States scallop men were progressively exploring offshore beds, and landings of Placopecten increased rapidly, especially after the substantial resources of Georges Bank and the Mid-Atlantic Bight were discovered. In 1939 more than 25 000 tonnes were harvested. The old whaling port of New Bedford, in Massachusetts, found a new vocation as the home of the offshore scallop fleet: two thirds of the total catch was brought in there. The second World War checked the growth of scalloping, but once the war was over it recovered quickly: by 1950 total production exceeded 50 000 tonnes, and the year 1960 witnessed landings of 100 000 tonnes (see Fig. 4). Meanwhile, early in the 1950s a few Canadian fishermen and processors who had had enough of the low yields of scallops from the Bay of

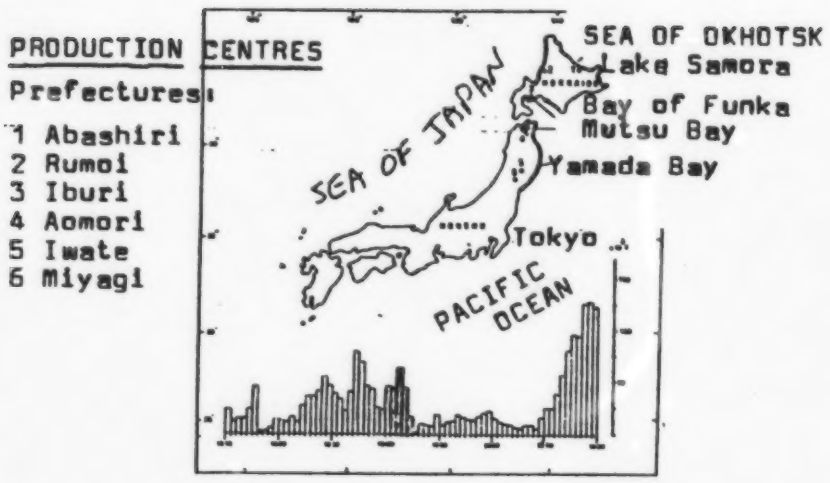

Fig. 3. Changes over time in Japan's production of Patinopecten scallops and main production centres today.

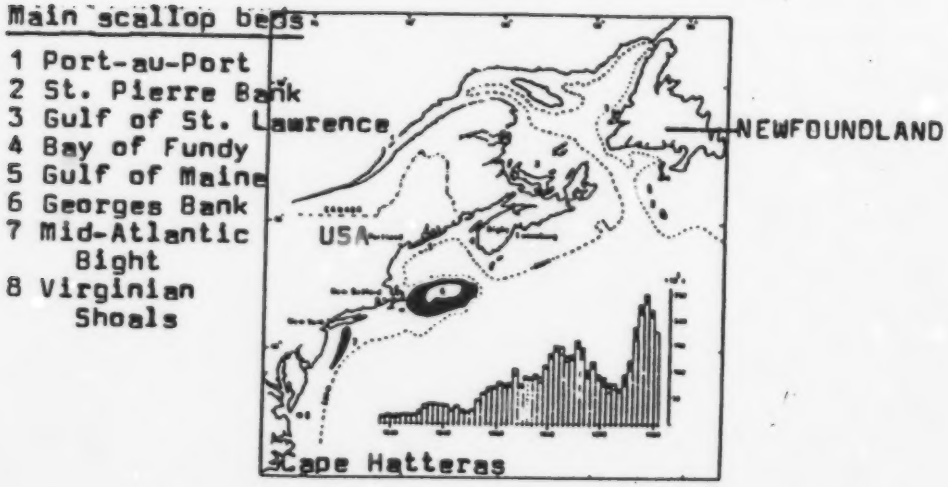

Fig. 4. Changes over time in North America's (USA + Canada) production of Pectinidae (white areas: Placopecten; shaded areas: Argopecten irradians; black areas: Argopecten gibbus). The map shows the main Placopecten scallop beds.

Fundy decided in their turn to try their luck offshore. Lack of experience and unsuitable boats meant disappointing results at first, but an excellent year class on Georges Bank in the late 1950s finally provided the Canadian scallop fishing industry with the impetus it needed, and production increased from less than 6000 tonnes in 1955 to over 60 000 tonnes in 1964. Catches fell off substantially in 1965, but large quantities of scallops were harvested further south, in the Mid-Atlantic Bight and on the Virginian Shoals, and for that reason the downward slide in total production was somewhat slower than it might otherwise have been; none the less, by 1973 total landings for the USA and Canada combined were less than 28 000 tonnes. From 1975 onward, however, recruitment rates among the Georges Bank population were so high that record quantities were harvested, with a 1978 peak of 230 000 tonnes (comprising 120 000 tonnes landed by American scallop fishermen and 110 000 tonnes landed by their Canadian counterparts). Meanwhile, bay scallop production had remained stable at approximately 5000 tonnes per year. Partly because of the decline in yields of Placopecten between 1965 and 1974, the scallop fleets now began to harvest a species related to the bay scallop but inhabiting deeper water (between 50 m and 120 m), namely the calico scallop (Argopecten gibbus), with the result that a scallop fishery based on the exploitation of that species was able to develop in Florida. Yearly landings of calico scallops quickly stablized at approximately 10 000 tonnes.

Although scallops had been harvested in the waters along the coasts of Europe since remote antiquity, the activity had been on a generally small scale until the second World War, with total yearly catches averaging somewhere between 3000 and 5000 tonnes. The main harvesting areas were the waters along the coasts of Normandy and Brittany in France and the west coast of Scotland. Catches consisted for the most part of Pecten maximus. Harvesting resumed only

slowly after the war, with production reaching a plateau of some 5000 tonnes by the late 1950s. In the course of the subsequent decade scallop fishing vessels began operating in Saint-Brieuc Bay once again, while in the Scottish fishery the beds of the Clyde were exploited more intensively, and consequently the total European catch had risen to 15 000 tonnes by 1970. England, Ireland and the Isle of Man all joined in, working the scallop beds of the English Channel and the Irish Sea. Production of Pecten maximus reached a peak of 32 000 tonnes in 1976 (see Fig. 5), but declined thereafter to a yearly total of approximately 25 000 tonnes as a result of the lower yields that by then were being obtained from Saint-Brieuc Bay and the eastern Channel. Concurrently, there was a very substantial expansion in the harvesting of scallop species belonging to the Chlamys group, largely owing to strong demand from the United States, to offset the decline in landings of Placopecten. Scallopers from Scotland and the Isle of Man were the first to go after Chlamys operculatis, and their opposite numbers from England, Ireland and France were not slow to follow their lead, while the Icelandic fleet, for its part, began to harvest Chlamys islandica. Great Britain's scallop production peaked in 1973 with landings of nearly 15 000 tonnes, while Ireland's production amounted to 9000 tonnes in 1980. Since 1976, total European production of scallops has fluctuated between 40 000 and 45 000 tonnes a year. France accounts for two thirds of all catches of Pecten species, while as regards Chlamys species, Great Britain and Ireland together account for roughly half the catch.

Other producing countries include Australia, New Zealand, Argentina, Brazil, Chile, South Africa, Korea, Taiwan, the Philippines and Indonesia. These countries' scallop fisheries, which are of relatively recent origin, bring in a combined total of between 20 000 and 30 000 tonnes yearly. It is probable that the USSR and China have developed scallop fisheries as well, but no statistical information about their production is currently available.

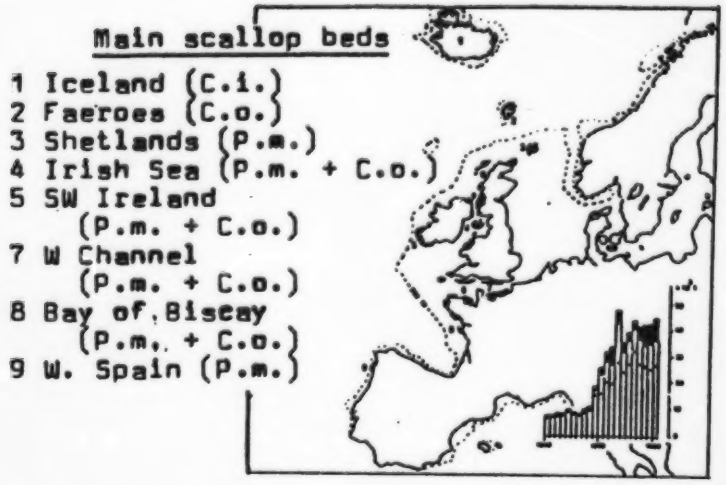

Fig. 5. Changes over time in European scallop production (white areas: Pecten maximus; shaded areas: Chlamys opercularis; black areas: Chlamys islandica).

Fig. 6. A Canadian offshore scallop dragger.

At present, dragnets are the type of gear most commonly used to harvest scallops, although where bottom conditions are favourable pole trawls or even otter trawls may sometimes be used to good effect. A drag will pick up between 5% and 30% of the scallops in its path. Scallop draggers are characterized by their powerful engines and sturdy construction. Approximately 0.5 H.P. is required for each kilogram of drag weight. The small boats (between 6 m and 15 m in length, with 50 to 200 H.P. engines) that work inshore scallop beds usually tow one or more small drags from 0.7 m to 2 m in width; this gear is readily manoeuvrable. Offshore scallop boats (between 20 m and 30 m in length, with 400 to 1200 H.P. engines) tow from 10 to 15 small drags simultaneously, or else two large drags, each of which is 5 m wide (see Fig. 6). Inshore scallop draggers never stay out longer than one day at a time, but a big deep-sea dragger from Canada or the United States will sometimes work for as long as two weeks before returning to port. The catch may be landed live, or the scallops may be shucked on board the vessel and the meat placed in cotton bags which are stowed in ice in the hold.

Scallop farming, or the Japanese model

Fishing for scallops is an activity marked by sharply fluctuating yields. The Japanese, who were the first to develop intensive harvesting techniques, had occasion to realize before anyone else how uncertain a business scalloping was. Years of abundance were followed by years of scarcity, and on occasion stocks were so severely depleted that natural regeneration became impossible. Accordingly, in order to maintain production at a high level, they decided to devote the bulk of their efforts to cultivating scallops rather than fishing for them, as we have seen. As a first step, they had to develop means of collecting

spat, and at once they encountered difficulties: not only is the period of adherence short, lasting only from two months to a year, but the byssus is a fragile entity, and furthermore scallop spat are able to detach themselves from their substrates and tend to do so as soon as they are disturbed.

In 1933 a scallop fisherman working the waters of Lake Samora found a cedar branch that had been immersed for several months, with scallop spat attached to it. This accidental discovery pointed the way to the first attempts to capture young scallops, using ground lines with cedar branches fastened to them as collectors. While the results were somewhat inconclusive, the basic technique had been developed. It was not until the early 1960s that the first major improvement to the technique was made, thanks to another scallop fisherman, this one from Mutsu Bay: he found that wrapping the cedar branches with small-mesh netting was an effective means of preventing the spat from escaping when the lines were lifted.

Since then, better collectors have been developed. Old nylon nets are commonly used nowadays, enveloped in small-mesh (5 mm on a side) netting bags; such collectors are easily handled and have a longer useful life. In the mid-1960s, it was unusual to capture more than a few dozen individuals per 80 cm x 40 cm collector in Mutsu Bay (the main production centre); by 1970, yields had increased to between 6000 and 10 000 specimens per collector, and by 1972 the total had risen to 50 000 to 60 000 per collector. This very substantial increase in yields has come about partly because intensive scientific research has made it possible to predict the period of adherence more accurately, and partly because the stock of genitors has grown as scallop cultivation has expanded. However, sizable fluctuations in yields still occur: the average number of specimens per collector has been as small as 500 to 1000 in some years. Accordingly, large numbers of collectors must be deployed in order

to ensure that the minimum requirements of cultivators can be met. Surplus spat is sold in other regions that have been less successful in their spat-collecting efforts.

At the time of capture, the spat range from 5 to 15 mm in size. As an initial measure, they are placed in small-mesh net baskets for precultivation; this step is essential as a means of protecting them from most of their predators. Within a few months they have grown to a size of between 3 cm and 6 cm and are ready either to be seeded directly on the bottom or to be raised in floating net cages of the "Japanese lantern" type (see Fig. 7), which are moored in sheltered bays. The former technique produces market-sized (10 to 13 cm) scallops in three to four years, the latter in two to three years, counting from the date of capture. At the present time, the cost of cultivating scallops is of the order of 150 to 200 yen per kilo.*

Production of 10 000 tonnes of adult scallops annually involves collecting approximately 200 million spat every year. This means that a cultivator must have between 50 000 and 200 000 collectors, between two and three million precultivation baskets, and 500 000 Japanese lanterns (if he uses the floating cultivation system) at his disposal. Furthermore, a great deal of labour is required: the ground lines must be fitted with their collectors and set, the collectors must be sorted, the spat must be placed in the precultivation baskets, the baskets and cages must be cleaned, and so on. In addition, the equipment must be replaced at intervals of from two to four years. Japanese scallop producers have organized co-operatives in an effort to enhance their output, and the results have been striking: Japan's total scallop production increased from 6000 tonnes in 1968 to over 120 000 tonnes in 1979. At the

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*1 yen was worth 2.5 centimes in 1980 and 3 centimes in 1983.

Fig. 7. "Japanese lanterns" of the type used in the cultivation of scallops.

present time, roughly one third of total production consists of specimens raised in floating cages and one third of specimens that were seeded on the bottom; the remainder consists of specimens harvested from natural beds, which have been able to maintain their populations more effectively because they are now reinforced with specimens produced by cultivators.

This gives us some idea of the substantial effort that has been put into scallop cultivation, not only by the fishermen who first thought of the idea and have put it into practice but also by the scientists whose work has made it possible to improve output and by the governmental authorities, which have contributed a sizable percentage of the necessary capital.

Since the 1970s at least ten other countries have attempted to adopt the Japanese model, but to date the results have been disappointing. The first obstacle is the difficulty of obtaining spat, and the second is the fact that labour accounts for such a large proportion of total costs. Numerous attempts to capture spat have been made in France, Great Britain and Ireland, and it appears that while Chlamys spat can be collected in large quantities easily enough, Pecten spat are another matter. The selection of a suitable site appears to be of critical importance: it must be well sheltered with only a weak current, but at the same time it must be sufficiently exposed to the open sea for the water to be of good quality. In addition, genitors must be sufficiently densely distributed that the level of reproduction will be high, and there must be eddies in the water to prevent the larvae from becoming dispersed. The lochs of Ireland and Scotland and the fjords along the coast of Newfoundland are eminently suitable for the collection of spat, but the cost (from 10 to 30 centimes per specimen) is still so high that in the short term at any rate there is no realistic possibility of developing large-scale scallop-raising operations.

Another approach to the problem of spat supply is direct production in hatcheries. The necessary techniques are known and commonly applied in the case of other bivalves such as oysters, quahogs and clams. In the case of scallops, however, such experimental operations as have been undertaken to date have not yielded very satisfactory results, mainly because of the heavy mortality that occurs among the larvae as the time of their metamorphosis approaches. None the less, enough progress has been made with hatchery techniques in recent years to suggest that this may well become a practicable approach within the next decade or so.

The cost of labour in high-income countries makes the floating cage cultivation system impractical, and accordingly investigators in Europe and North America have increasingly focussed their efforts on techniques involving the seeding of juveniles on the sea bed. A measure of discipline and solidarity among producers is a prerequisite for success here: it will be necessary to set up structures within which funding can be provided, tasks and operational areas assigned, profits distributed, and the whole industry regulated. Organizations of this type frequently prove to be difficult to establish, as they run directly counter to current practices in the fishery sector.

Lastly, changes in the situation with respect to landings of scallops and with respect to market prices will also affect the outlook for scallop cultivation. Declining world catches would tend to encourage research and development efforts in these countries, and as a result scallop farming would become profitable enough to grow and develop comparatively quickly. If catches were to increase, on the other hand, prices would tend to stagnate, and this would mean that a scallop cultivator would be confronted with relatively higher costs and smaller profit margins.

Marketing and markets

Three countries, the United States, Japan and France, account for 90% of the world's consumption of scallops. In Japan the meat is cut up in slender strips and eaten raw (this is the dish known as sashimi). However, scallops harvested at remote production centres that are too far away from the great cities for the product to be sold in this form are shucked and shipped to market boiled, dried or frozen. French consumers prefer live scallops, complete with their coral. The muscle, the coral and the mantle are all used, prepared in various fashions. In North America, only the muscle meat is marketed; as a rule it is sold frozen and sometimes breaded.

The yield, in terms of edible parts, thus varies from 10% to 30% of the live weight, depending on the country. The price of a kilogram of whole scallops is of the order of 150 to 250 yen (4 to 7 French francs) in Japan and 7 to 12 francs in France, while a kilo of muscle meat costs between $10 and $12 (70 to 90 French francs) in the United States. The price paid by the final consumer may be twice or even three times as high.

In exporting countries, transport and storage costs and customs duties cut into the prices paid to producers; in Canada (which is the main exporting country), for example, producers earn 30% to 40% less than their counterparts in the United States.

The substantial increase in production that has occurred over the past twenty years has been adequately absorbed by the three traditional consuming countries. In those countries, scallops continue to be regarded as a luxury product, and demand has reflected rising standards of living (in particular, demand has paralleled the growing trend for people to eat out in restaurants). Another aspect is that the product has become more widely available, while

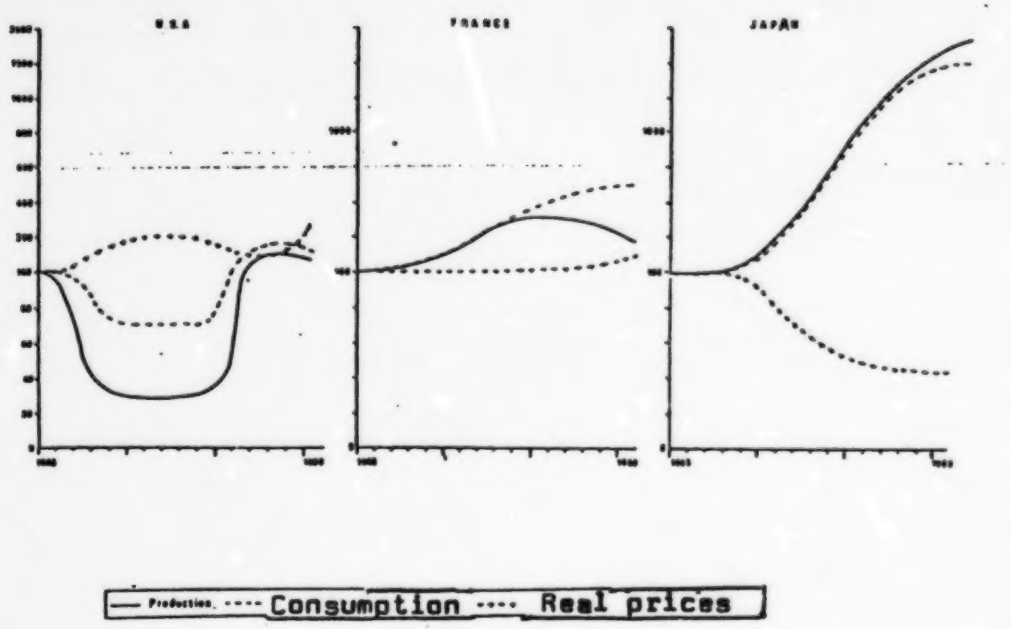

Fig. 8. The main trends in scallop production and markets in the USA (Placopecten), France (Pecten) and Japan (Patinopecten). 1965 is used as the base year (base 100).

consumer awareness has increased: scallops are commonly sold in supermarkets nowadays. Lastly, the processing industries are capable of canning, freezing and drying substantial quantities of scallops, and during periods when production is high these activities tend to exert a regulating effect on the interplay of supply and demand.

However, the prices paid to producers have been characterized by different patterns of movement in the three producing countries. In the United States, for example, prices increased by a factor of 2.5 in constant dollar terms between 1965 and 1980; in France they rose by 30% during that same period, while in Japan there was a decline of some 50% in real terms (see Fig. 8). These divergent trends are to be explained by the changes specific to each of the three markets in question that occurred during that period.

In the United States, changing levels of Placopecten production have exerted a strong influence on prices (see Fig. 9). The years between 1967 and 1975 were a period of scarcity, and the price of scallops rose steeply. Between 1975 and 1978, on the other hand, production increased sharply and prices fell. Another reversal of the situation has occurred since 1979, as catches have declined and the product is again in short supply. In France, the upward trend in landings of Pecten maximus between 1966 and 1973 was accompanied by a proportionate strengthening of demand, with the result that prices remained stable, in real terms, during that period. Since 1974, production in the French fishery has fallen off and prices have risen in real terms (see Fig. 10), despite an increased flow of imports. In Japan, until 1976 the supply of Patinopecten scallops increased more rapidly than demand for them, and consequently the value of the product, in real terms, declined steadily and producers' profits shrank. Since that year, however, production has grown at a somewhat slower rate, while greater quantities have been exported, and the result has been that the price situation has become stabilized to some extent.

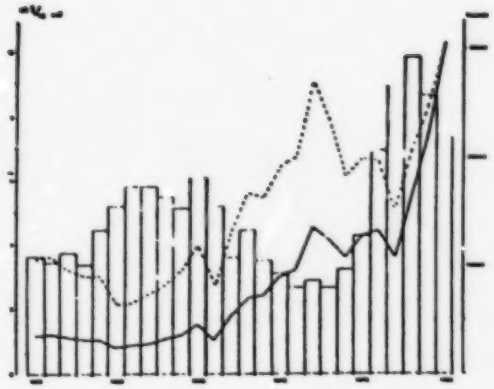

Fig. 9. Changes over time in current prices and real prices (1980 value) paid to United States producers. The histograms represent the total Placopecten supply (USA + Canada) in tonnes of muscle meat.

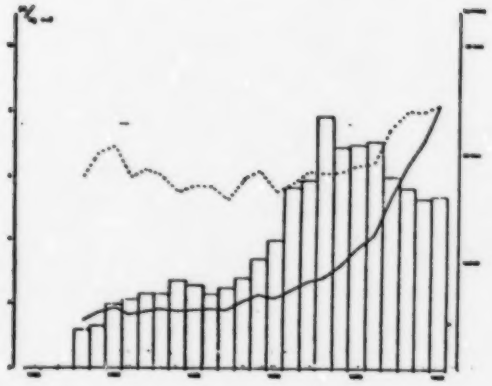

Fig. 10. Changes over time in current prices and real prices (1980 value) paid to French producers. The histograms represent France's total production of Pecten maximus.

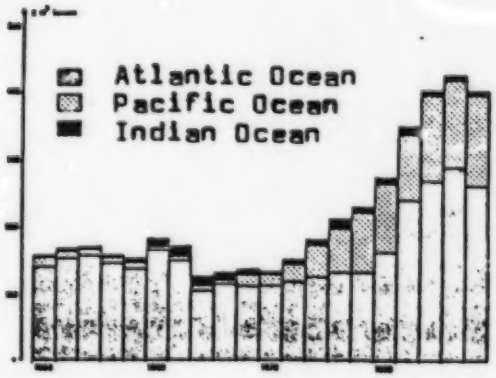

Fig. 11. Changes over time in world scallop production as recorded by FAO since 1960.

Between 1965 and 1980, annual per-capita consumption in the United States rose from 0.7 kg (live weight equivalent) to 1.1 kg, although the years from 1967 to 1974 were marked by a considerable deline (to between 0.5 and 0.6 kg per year) owing to the low level of North American production during that period. In France, yearly per-capita consumption, which was approximately 0.2 kg in 1965, had increased to 0.8 kg by 1975; since then, consumption has grown more slowly, attaining 0.9 kg per capita by 1980. Japan's yearly per-capita consumption was a mere 0.08 kg in 1965, but in the course of the subsequent fifteen years it increased twelvefold, and by 1980 the figure stood at 0.9 kg. At present, however, consumption in Japan appears to be levelling off.

The outlook

The strong growth in world scallop production that occurred in the 1970s was the result of the doubling of catches from the Atlantic and the spectacular increase in Japanese output; the Indian Ocean continued to account for only a very small fraction of the total (see Fig. 11).

As regards the Atlantic, the sudden leap in North American production from 60 000 tonnes in 1973 to 250 000 tonnes in 1978 was to a large extent the result of a greater fishing effort fuelled by the exceptional abundance of Placopecten and the rising price of scallops in the United States market during those years (the value of the product increased in real terms by a factor of 2.5 between 1965 and 1980). This situation cannot last: the main scallop beds are already displaying symptoms of overharvesting. In Europe, most beds of Pecten are also being intensively worked, and landings have been stable at approximately 25 000 tonnes since 1975. The only species that still hold out some prospects for growth are the substitute species such as Chlamys opercularis,

C. islandica and Argopecten gibbus. Systematic harvesting of these species, however, will require long-range scallop fishing vessels equipped for mechanized shucking of the catch at sea. On the whole, the short-term outlook is for a decline in production from the North Atlantic as harvesting slackens to a more moderate level, and this will give the stocks a chance to recover.

In the Pacific, the Japanese fishery accounts for virtually all production. After achieving vigorous growth during the 1970s, with output increasing from 6000 tonnes in 1968 to 120 000 tonnes in 1979, Japan is now moving in the direction of somewhat slower growth: its objective for 1985 is 150 000 tonnes. The steep decline in the value of the product (a matter of 50% in real terms within ten years) has meant smaller profits for scallop cultivators. The expansion of other forms of marine aquaculture, furthermore, may be expected to result in the saturation of some cultivation sites. However, neighbouring countries such as Korea, and also the USSR, are likely to follow Japan's lead, and hence the Pacific may well come to account for a progressively larger share of world production as time goes on.

In the case of the scallop fisheries of other producing countries, growth in output has by no means ceased, even though some of the beds worked by their scallop draggers are already being subjected to intensive harvesting. The explanation of this phenomenon is that the systematic identification of scallop resources has not yet been completed. Continued strong demand in the United States and France and the increasing popularity of scallops among the consumers of other high-income countries such as Great Britain, West Germany and Belgium imply a growing potential export market for third countries, and this should stimulate harvesting activity in countries whose scallop resources are as yet unexploited. A number of technical obstacles remain, however, and on balance it would seem probable that world production will grow only slowly during the

1980s. Most of the world's remaining unexploited scallop beds are located along the coasts of developing countries.

As yet not much is known about the world's total potential scallop resources, since little scientific research has been devoted to the tasks of exploration and identification, apart from a few studies that have been conducted in some of the developed countries. The small size of most beds and the difficulty of capturing scallops without appropriate boats and fishing gear constitute severe constraints on the preparation of a systematic inventory of the various species in question.

SUMMARY BIBLIOGRAPHY

Bourne, N., 1964. Scallops and the offshore fishery of the Maritimes. Fish. Res. Board of Canada, Bull. No. 145, 60 pp.

Buestel, D., Arzel, P., Cornillet, P. and Dao, J.-C., 1977. La production de juvéniles de coquilles Saint-Jacques (Pecten maximus) (the production of juvenile scallops [Pecten maximus]). Proceedings of CNEXO symposia, 4: 307-315.

Buestel, D. and Dao, J.-C., 1979. Aquaculture extensive de la coquille Saint-Jacques: résultats d'un semis expérimental (extensive cultivation of scallops: the results of an experimental seeding operation). La Pêche maritime, 1215: 361-365.

Caddy, J.-F. and Lord, E. I., 1968. Recent developments in the Georges Bank scallop fishery. ICNAF, Redbook, Part III, pp. 89-93.

Choat, J. H., 1960. Scallop investigation in Tasman Bay, 1959-1960. New Zealand Marine Department Fisheries Technical Report No. 2.

Chaussade, J., 1981. La pêche aux pétoncles dans les Provinces maritimes du Canada (the scallop fishery in Canada's Maritime Provinces). La Pêche maritime, 1237: 224-229.

Dickie, L. M., 1955. Fluctuations in abundance of the giant scallop (Placopecten magellanicus) in the Digby area of the Bay of Fundy. Fish. Res. Board of Canada, 12 (6): 797-856.

Dickie, L.M. and Medcof, J. C., 1963. Causes of Mass Mortalities of Scallops (Placopecten magellanicus) in the Southwestern Gulf of St. Lawrence. J. Fish. Res. Board of Canada, 20 (2): 451-479.

Dupouy, H., 1978. L'exploitation de la coquille Saint-Jacques, Pecten maximus, en France. 1re partie: Présentation des pêcheries (the harvesting of scallops [Pecten maximus] in France. Part 1: introduction to the fishery). Science et Pêche, Bull. Inst. pêches marit., 276, 11 pp.

Dupouy, H., de Kergariou, G. and Latrouite, D., 1983. L'exploitation de la coquille Saint-Jacques, Pecten maximus, en France. 2e partie: Évaluation et gestion du stock de la baie de Saint-Brieuc (the harvesting of scallops [Pecten maximus] in France. Part 2: estimation and management of the Saint-Brieuc Bay population). Science et Pêche, Bull. Inst. pêches marit., 331, 11 pp.

Lucan, A., 1980. Le rôle du naissain d'écloserie dans l'aquaculture des bivalves (the role of hatchery-produced spat in bivalve aquaculture). La Pêche maritime, 1238: 294-297.

Masson, J., 1972. The Scottish Fishery for Scallops and Queens. Scott. Fish. Info. Pamphl., 11 pp.

Muller-Feuga, A. and Querellou, J., 1973. Exploitation de la coquille Saint-Jacques au Japon (scallop production in Japan). Rapports sc. et techn. du CNEXO, 14, 83 pp.

Naidu, K. S., 1970. Reproduction and breeding cycle of the giant scallop, Placopecten magellanicus (Ginelin), in Port au Port Bay, Newfoundland. Can. Journ. of Zoology, vol. 48, No. 5: 1003-1012.

Posgay, J. A., 1957. Sea scallop boats and gear. Fish and Wildlife Service, Fishery Leaflet 442, 11 pp.

Querellou, J., 1975. Exploitation des coquilles Saint-Jacques (Patinopecten yessoensis) au Japon (the production of scallops [Patinopecten yessoensis] in Japan). A.D.A. Publication No. 2.